

First edition
2016-11-15

**Gasoline engines with direct
injection — Cleanliness assessment of
fuel injection equipment**

*Moteurs à essence — Evaluation de propreté pour équipement
d'injection de combustible*



Reference number
ISO 19724:2016(E)



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 22, *Road vehicles*, Subcommittee SC 34, *Vehicle propulsion, powertrain and powertrain fluids*.

Introduction

Modern fuel injection systems contain many closely controlled clearances and rely on the fuel-flowing characteristics of small orifices. Thus, they require the close control of sources of contamination in order to maintain the operational performance demanded of them throughout their design life. To this end, such systems are designed with integral fuel-filtration equipment, which reduces the amount of potentially damaging debris that could enter the system from external sources.

However, contamination of the fuel injection system can also occur internally, from system use or wear, from equipment servicing, or as a result of the original supplier's manufacturing and assembly processes. The focus of this document is on the latter source of contamination and is thus concerned with the assessment of the cleanliness of the fuel injection equipment as originally supplied to the engine manufacturer.

Fuel injection systems comprise a number of components. These are the low pressure elements (fuel tank, pipe-work, filters, lift pump, etc.), a high pressure fuel pump, a high-pressure pipe, a fuel rail with a high pressure sensor and fuel injectors.

During the preparation of this document, the importance of care in the handling and measurement of contamination samples was clearly recognized. Moreover, the low levels of contaminant with fuel injection equipment make this a particularly difficult task. For this document to be used meaningfully as an indicator of component cleanliness and a driver towards higher quality standards, extreme attention to detail is required of the user. Verification requirements for the test equipment used are therefore emphasized. Helpful standards for appropriate conditions and handling are given in the bibliography.

It is not always clear what level of cleanliness is sufficient for rated performance and life time on a cost-effective basis. The actual quantitative levels can only be set in relation to other parameters, agreed between the manufacturer, supplier and user. This document provides a set of procedures for evaluating the cleanliness of fuel injection equipment and a framework for a common measurement and reporting.

Gasoline engines with direct injection — Cleanliness assessment of fuel injection equipment

WARNING — Application of this document may involve the use of hazardous materials, operations and equipment. This document does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices and determine the applicable regulatory limitations prior to use.

1 Scope

This document specifies cleanliness assessment procedures for evaluating the amount of debris present on the clean side of the constituent parts of high pressure gasoline direct fuel injection systems. The presence of such debris could lead to a reduction in the system's operational performance.

While other International Standards (e.g. ISO 16232 series) relate to the cleanliness of different types of components used in road vehicle fluid circuits, this document focuses on the special procedures applied for the components of gasoline direct fuel injection systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 12345, *Diesel engines — Cleanliness assessment of fuel injection equipment*

ISO 14644-1, *Cleanrooms and associated controlled environments — Part 1: Classification of air cleanliness by particle concentration*

ISO 16232-3:2007, *Road vehicles — Cleanliness of components of fluid circuits — Part 3: Method of extraction of contaminants by pressure rinsing*

ISO 16232-5:2007, *Road vehicles — Cleanliness of components of fluid circuits — Part 5: Method of extraction of contaminants on functional test bench*

ISO 16232-7, *Road vehicles — Cleanliness of components of fluid circuits — Part 7: Particle sizing and counting by microscopic analysis*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

4 Procedures

4.1 General

All tests shall be carried out in a clean laboratory environment. Failure to achieve a satisfactory blank test level of contamination could indicate unsuitable control of test conditions. Clean room conditions according to ISO 14644-1, class 8, are recommended as a minimum for these procedures.

The appropriate method to determine the required amount of fluid is by use of an extraction curve, as described in ISO 16232-3:2007, 6.2 and ISO 16232-5:2007, 6.2 (see also ISO 16232-3:2007, Figure 1 and ISO 16232-5:2007, Figure 1). In order to avoid each laboratory finding a different amount of fluid to be required, a guideline for the volume is given here for each component.

The blank tests described in ISO 16232-3:2007, 6.3 and ISO 16232-5:2007, 6.3, are important procedures to check the quality of the laboratory equipment and shall be carried out once a week.

Before starting the test procedure, the outer surface of the component or assembly shall be thoroughly cleaned by using a fluid like for the cleanliness assessment.

This document covers the following components of the fuel injection equipment:

- high pressure pump;
- injector;
- rail;
- high pressure pipe;
- high pressure sensor.

4.2 General test conditions

The following conditions are valid for all the components of the injection equipment.

- Medium: Gasoline test fluid (hydrocarbon similar to gasoline).

For such components which during the production process did not come into contact with hydrocarbons, deionised water according to ISO 3696, Grade 3 with detergent also is possible (e.g. for pipes, rails, high pressure sensors).

- Temperature: Room temperature.
- Outlet pressure: Atmosphere.
- Pre filtration: $\leq 5 \mu\text{m}$.
- Contaminant filter: Cellulose filter $5 \mu\text{m}$ to $8 \mu\text{m}$.

4.3 High pressure pump

4.3.1 Method A

This test method refers to ISO 16232-5. The test of the high pressure pump shall be carried out by operating the pump on a functional test bench close to the conditions of the engine. This concerns, for example, plunger stroke, driving frequency, fuel flow. The pump under test is assembled to a cam box and driven by an electric motor.

Care shall be taken that no contamination from the outside surface of the connectors for fluid inlet and for fluid outlet is transferred to the fluid circuit.

Inlet pressure	Operation	Fluid quantity	Point of discharge
0,5...2 MPa (absolute)	Pump in operation 300 rpm to 1 500 rpm steady-state	1,8 l to 2,5 l Other quantities to be proven by extraction curve as per ISO 16232-5	Pump high pressure outlet

Method A is the preferred method for the high pressure pump.

4.3.2 Method B

If Method A cannot be applied for any technical or economical reason, Method B shall be used. This test method refers to ISO 16232-3 with pressure rinsing.

Inlet pressure	Operation	Fluid quantity	Point of discharge
0,1...0,5 MPa (absolute)	Flushing with help of a pump or of a syringe	$\geq 0,2$ l Other quantities to be proven by extraction curve as per ISO 16232-3	Pump high pressure outlet

4.4 Injector

The injector shall be operated by applying the electrical energising like at the engine. The resulting vibrations and pressure pulsations are considered to be essential for removing the contamination and bringing it out of the injector. The injection period (energising time) may be increased to about 90 % of the total cycle in order to get a high through flow to wash the particles out and to reach the required fluid quantity in an appropriate time.

The flow direction shall be reverse to the injection direction (with the internal fuel filter removed) in order to ensure that the orifices of the injector will not retain any particles. Only for such types of injectors where the internal filter cannot be removed that the normal flow direction shall be applied.

Inlet pressure	Operation	Fluid quantity	Point of discharge
0,5 ... 20 MPa (absolute)	Flushing from nozzle holes to injector inlet (reverse direction) with injector in operation (dynamic) with filter removed. If filter cannot be removed, flushing in injection direction. Energising frequency: 1 000 min ⁻¹ to 2 000 min ⁻¹ Energising time: approximately 90 % of the injection cycle	1 l for "dry" ^a injectors, 0,2 l for "wet" ^a injectors	Injector inlet, inlet filter of injector removed. If filter cannot be removed, injector outlet.

^a "Dry" injectors did not see any fluid after being assembled, while "wet" injectors were tested with fluid.

4.5 Rail

The inlet and each of the outlets shall be engaged in the through flow one by one, with the other outlets closed.

Inlet pressure	Operation	Fluid quantity	Point of discharge
0,1... 0,5 MPa (absolute)	Flushing with help of a pump or hand flushing by a syringe into each outlet, one by one, with the other outlets closed. Or, into the inlet and through all the outlets one by one	Flow for each outlet $\geq 0,3$ l. Other quantities to be proven by extraction curve as per ISO 16232-3	Inlet of the rail, respectively, the outlets one by one

4.6 High pressure pipe

Inlet pressure	Operation	Fluid Quantity	Point of discharge
0,1... 0,5 MPa (absolute)	Flushing with help of pump or of syringe	≥ 1 l	Pipe end

This procedure may also be applied for the low pressure tube from the fuel filter to the high pressure pump.

4.7 High pressure sensor

Inlet pressure	Operation	Fluid Quantity	Subject of flushing	Place of collecting
Atmosphere	Flushing with help of syringe	$\geq 0,1$ l	High pressure face and pressure port	Vessel

5 Analysis of particles

The analysis of the particles found on the filter shall be carried out according to ISO 16232-7.

6 Reporting of results

The cleanliness of the components shall be designated by using either

- the Fuel Injection Equipment Cleanliness Code (FIECC), as defined in ISO 12345:2013, Clause 7, or
- a table showing the requirements by the size classes (range) with an allowable particle count for each class.

Bibliography

- [1] ISO 16232-1, *Road vehicles — Cleanliness of components of fluid circuits — Part 1: Vocabulary*
- [2] ISO 18413, *Hydraulic fluid power — Cleanliness of components — Inspection document and principles related to contaminant extraction and analysis, and data reporting*

